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(54) **DEFLECTORS FOR CONTROLLING ENTRY OF FLUID LEAKAGE INTO THE WORKING FLUID FLOWPATH OF A GAS TURBINE ENGINE**

(75) Inventors: **Sami Girgis**, Montréal (CA); **Remo Marini**, Montréal (CA)

(73) Assignee: **Pratt & Whitney Canada Corp.**, Longueuil, Québec (CA)

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F01D 11/00 (2006.01)

(52) **U.S. Cl.** .... **416/193 A**; 415/116; 415/168.1; 415/208.1

(58) **Field of Classification Search** .... 416/95, 416/193 A, 219 R, 239, 248; 415/115, 116, 415/168.1, 168.2, 168.4, 208.1, 208.2, 208.5
See application file for complete search history.

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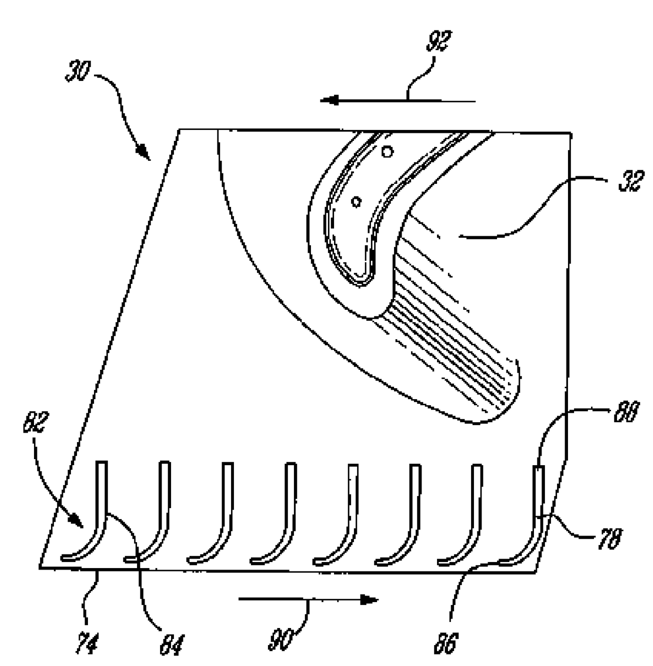
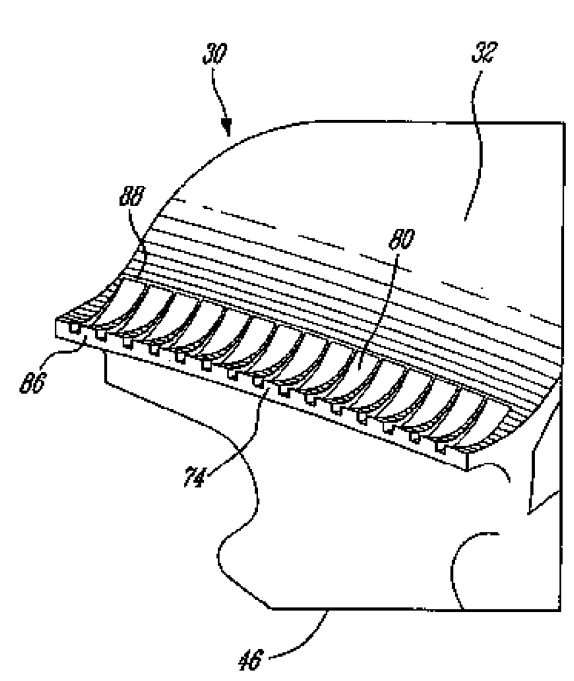
Primary Examiner—Richard A. Edgar
(74) *Attorney, Agent, or Firm*—Ogilvy Renault

(57) **ABSTRACT**

A deflector arrangement is provided for improving turbine efficiency by imparting added tangential velocity to a leakage flow entering the working fluid flowpath of a gas turbine engine.

20 Claims, 5 Drawing Sheets





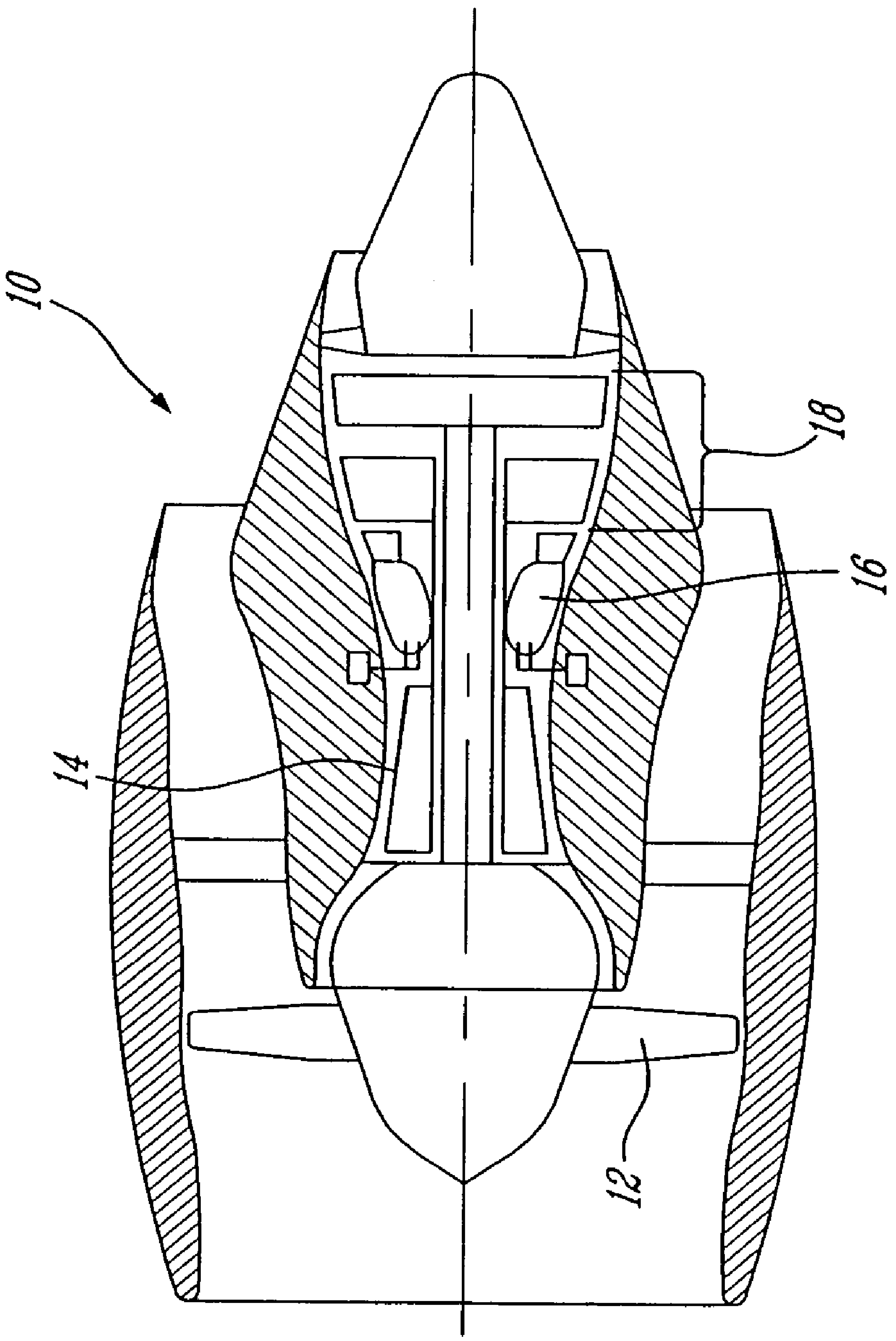


Fig. 1

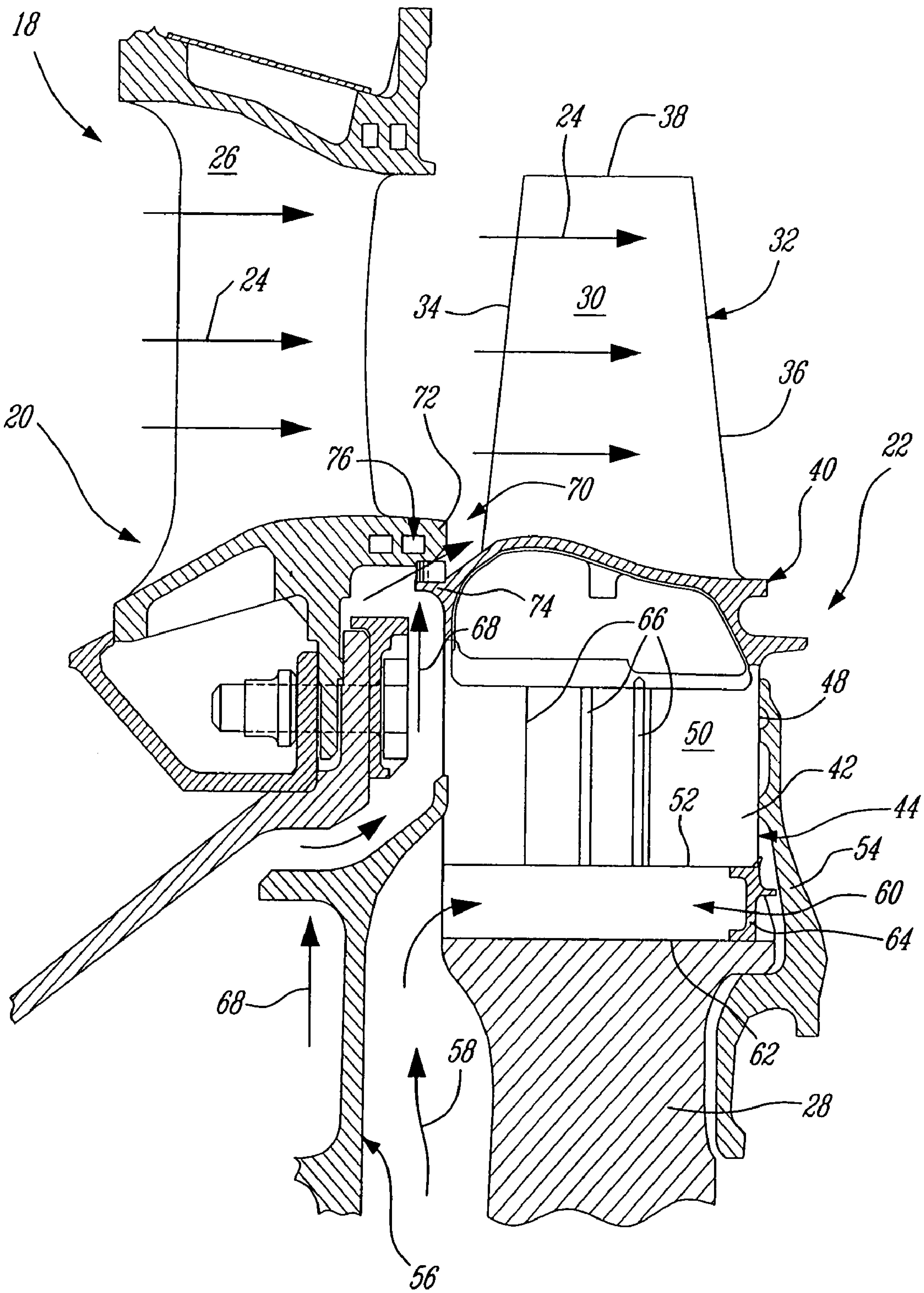

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Fig. 2

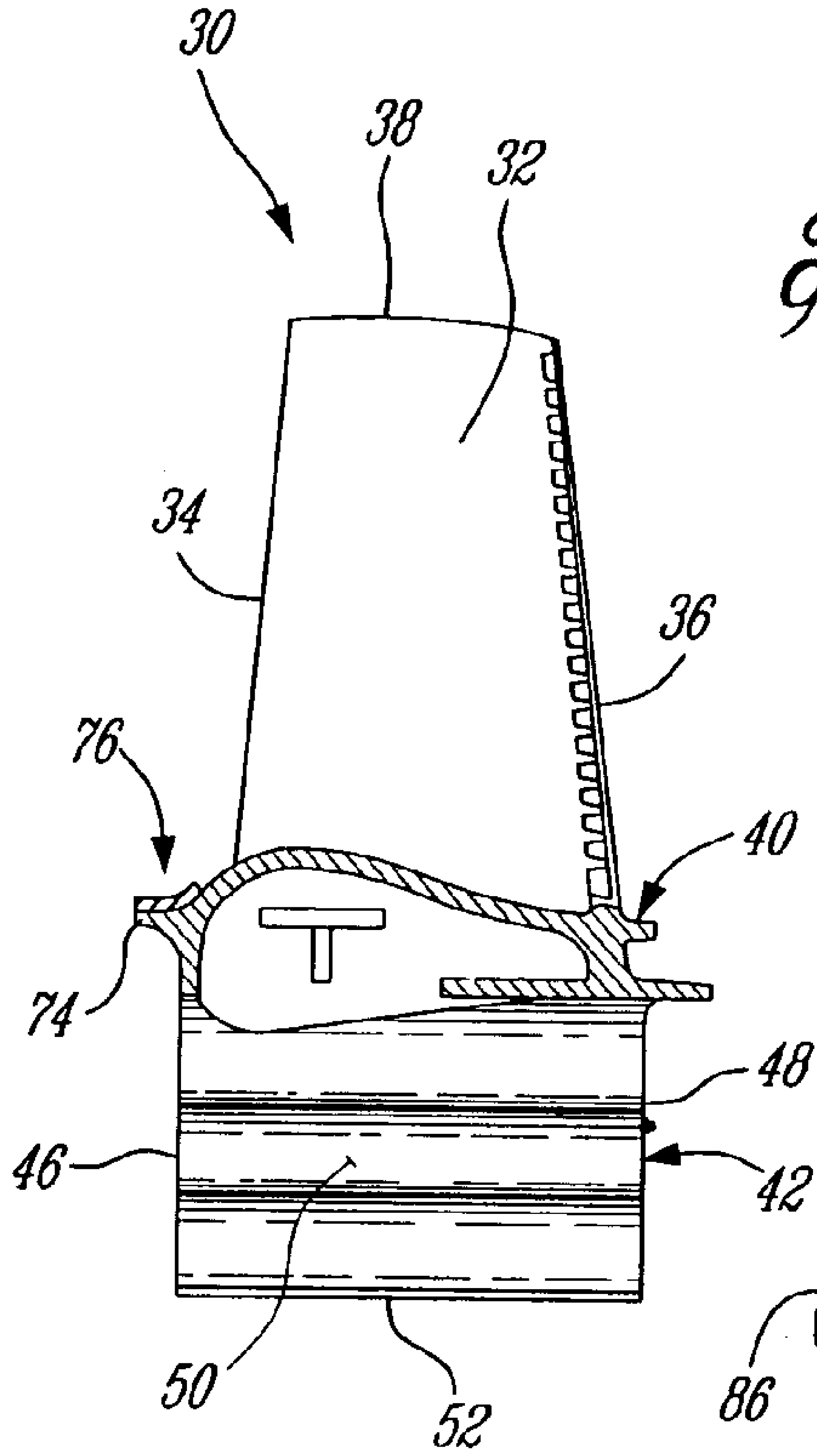

Fig. 3

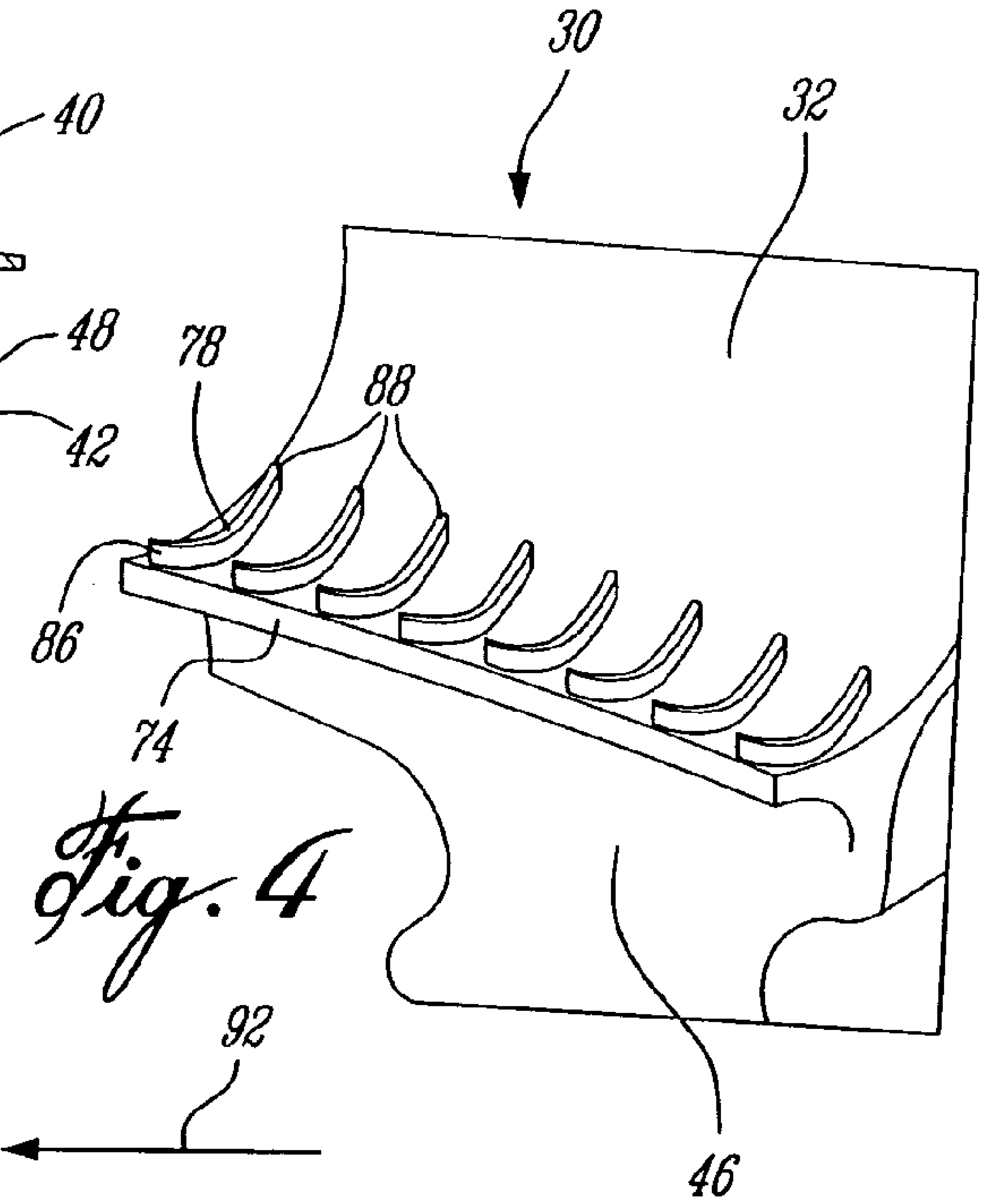

Fig. 4

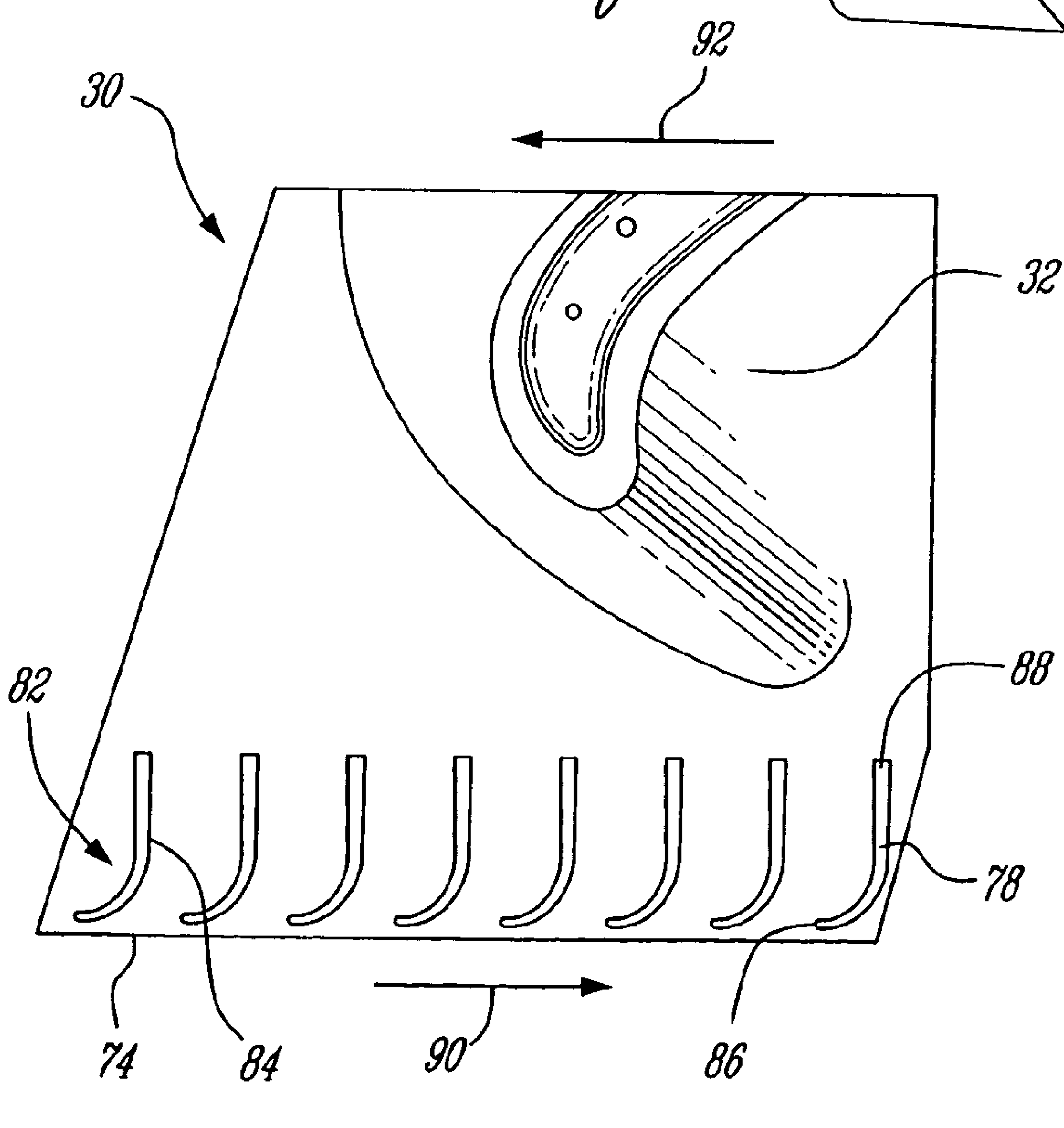

Fig. 5

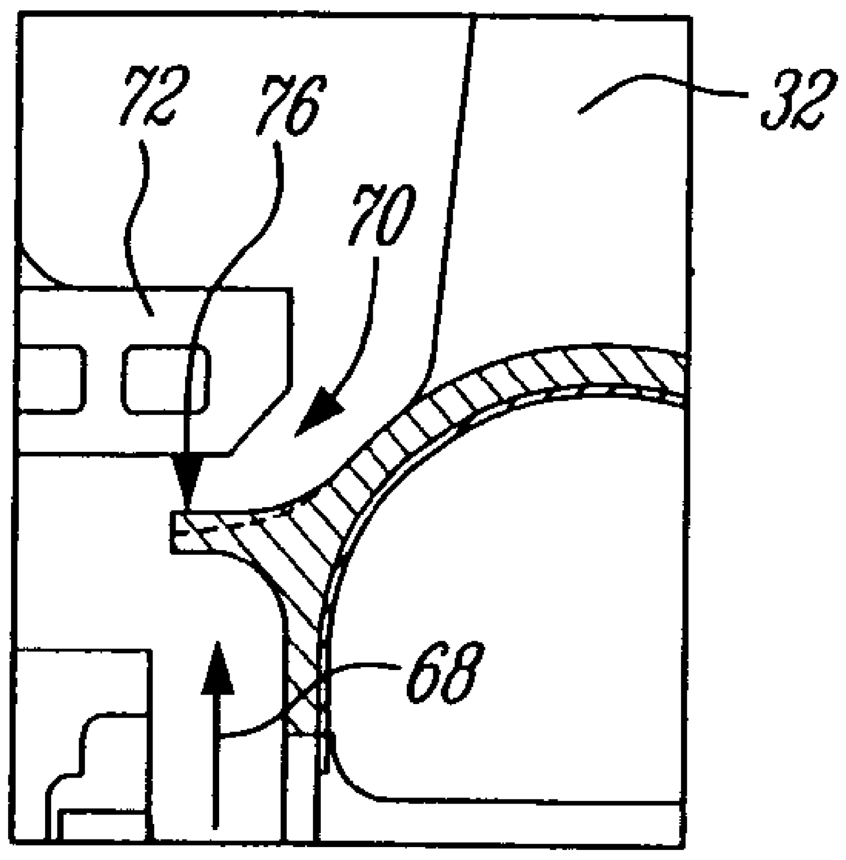

Fig. 6

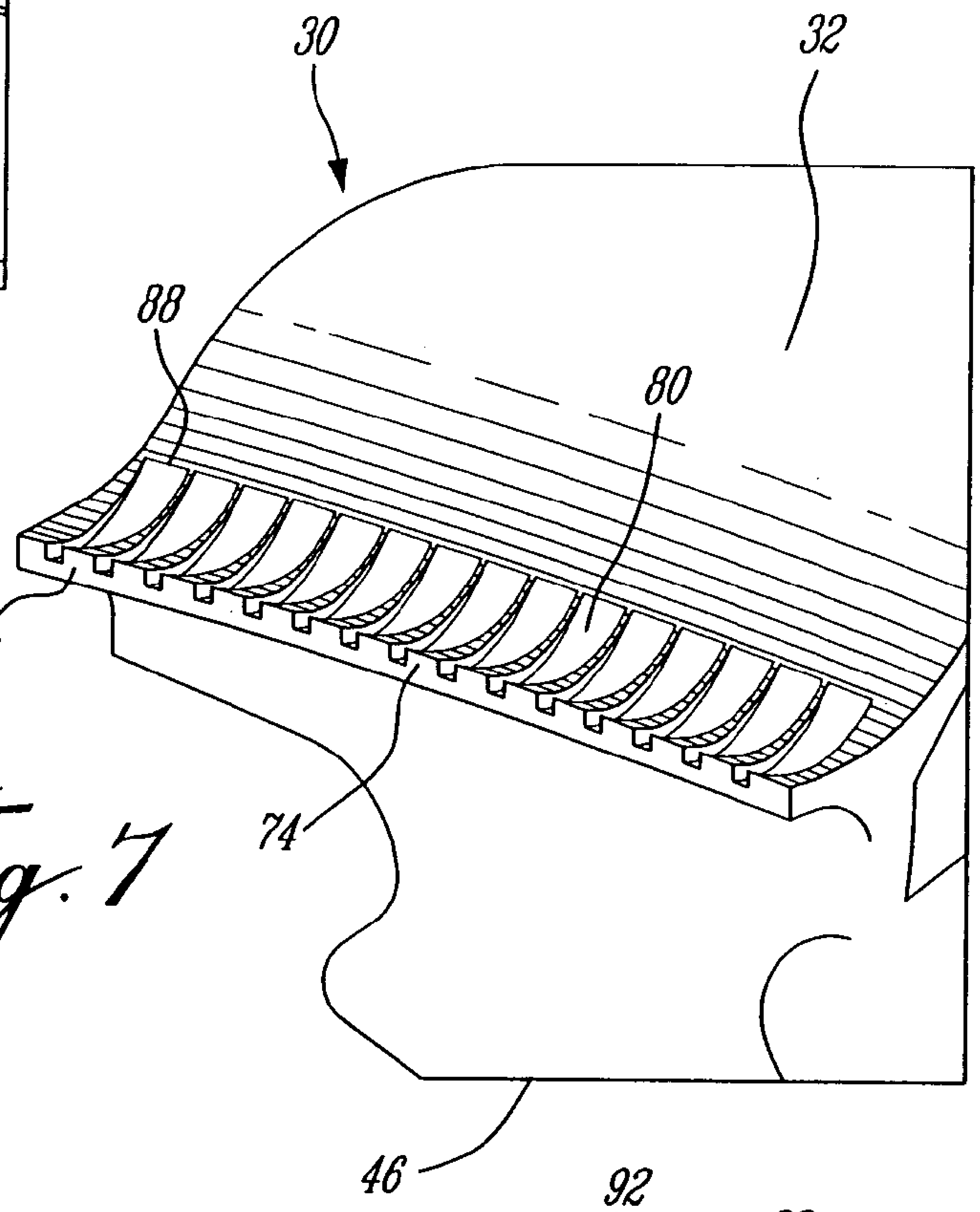

Fig. 7

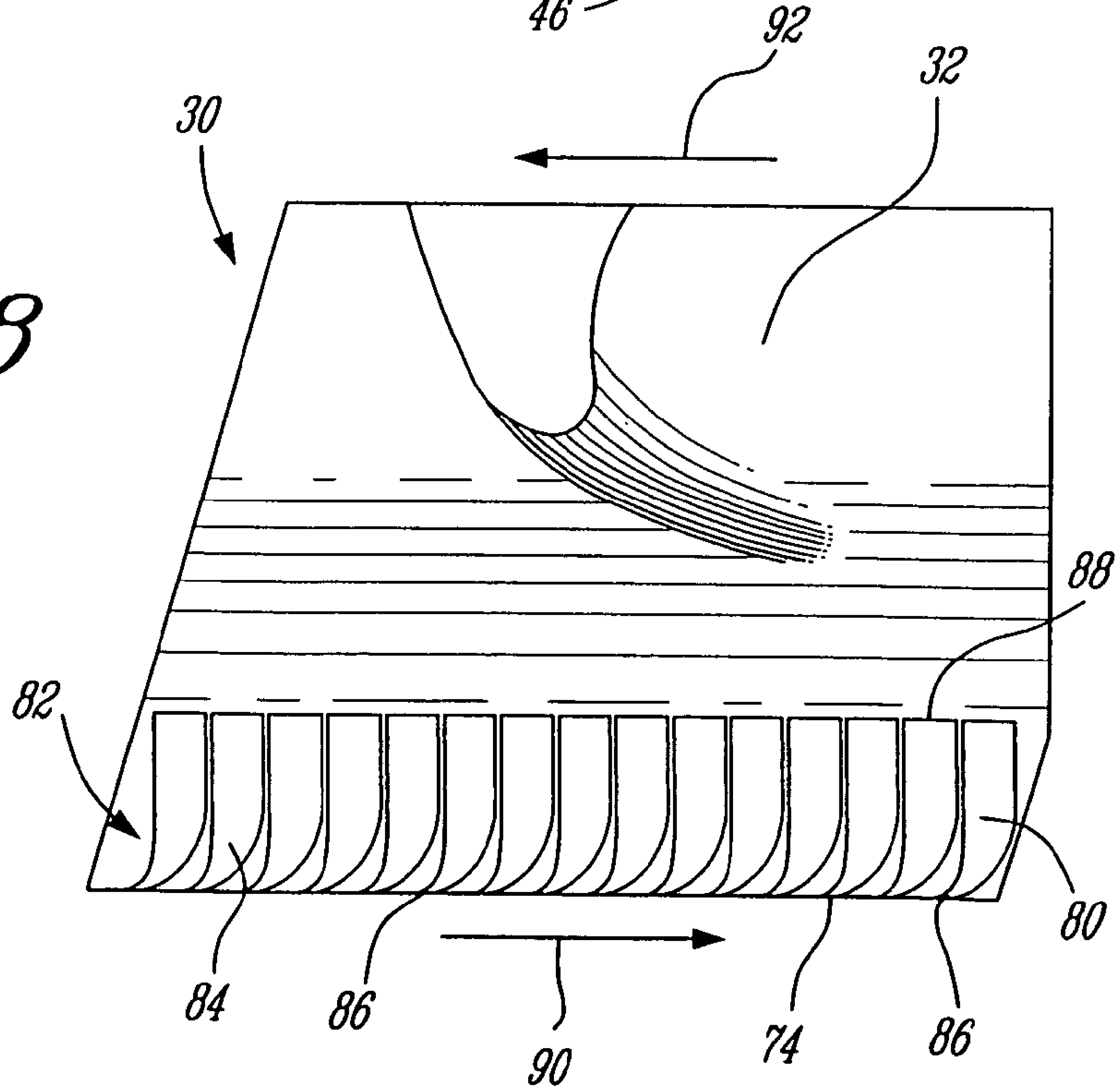

Fig. 8

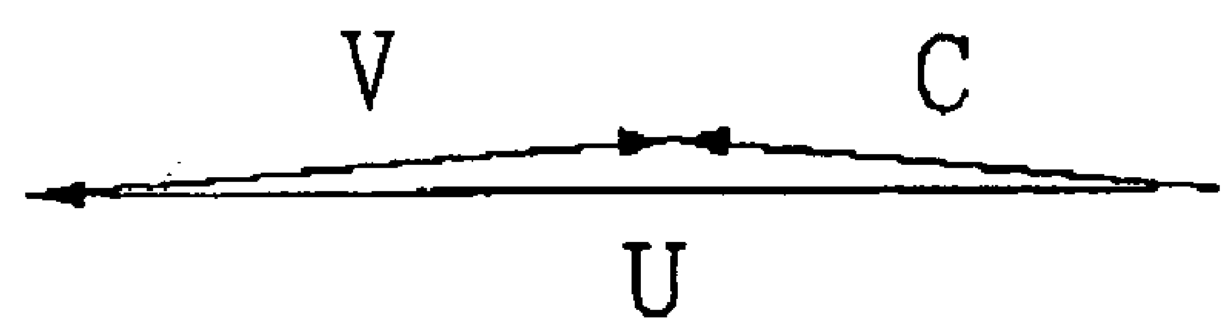

Fig. 9

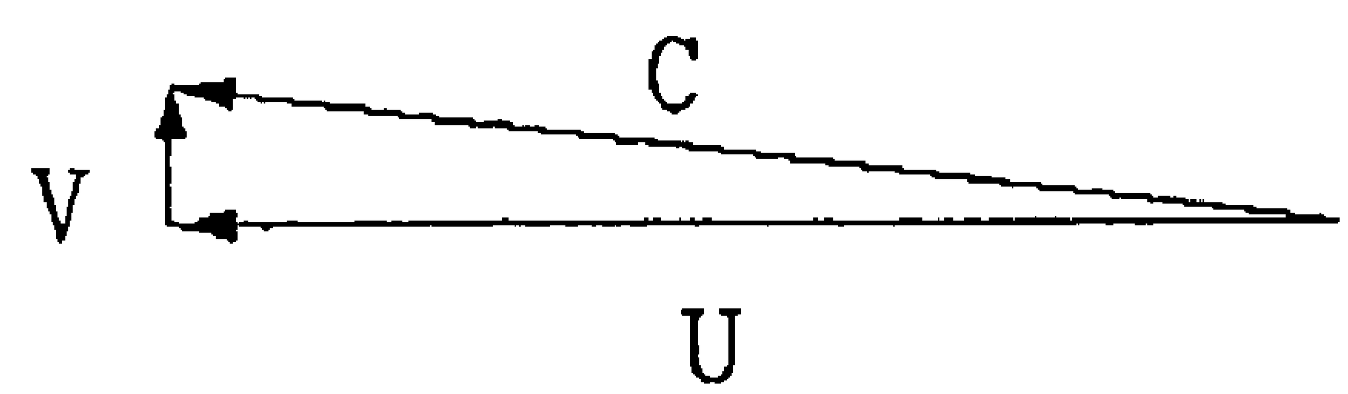

Fig. 10

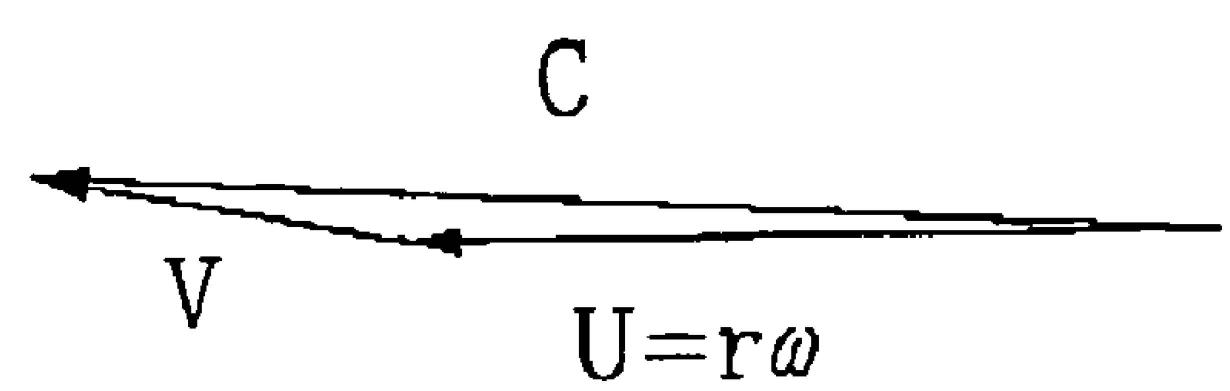

Fig. 11

DEFLECTORS FOR CONTROLLING ENTRY OF FLUID LEAKAGE INTO THE WORKING FLUID FLOWPATH OF A GAS TURBINE ENGINE

TECHNICAL FIELD

The invention relates generally to a deflector for redirecting a fluid flow exiting a leakage path and entering a gaspath of a gas turbine engine.

BACKGROUND OF THE ART

It is commonly known in the field of gas turbine engines to bleed cooling air derived from the compressor between components subjected to high circumferential and/or thermal forces in operation so as to purge hot gaspath air from the leakage path and to moderate the temperature of the adjacent components. The cooling air passes through the leakage path and is introduced into the main working fluid flowpath of the engine. Such is the case where the leakage path is between a stator and a rotor assembly. In fact, at high rotational speed, the rotor assembly propels the leakage air flow centrifugally much as an impeller.

Such air leakage into the working fluid flowpath of the engine is known to have a significant impact on turbine efficiency. Accordingly, there is a need for controlling leakage air into the working fluid flowpath of gas turbine engines.

SUMMARY OF THE INVENTION

It is therefore an object of this invention to provide a new fluid leakage deflector arrangement which addresses the above-mentioned issues.

In one aspect, the present invention provides a gas turbine engine including a forward stator assembly and a rotor assembly, the rotor assembly drivingly mounted to an engine shaft having an axis, the rotor assembly having a plurality of circumferentially distributed blades that extend radially outwardly into a working fluid flowpath, a leakage path leading to the working fluid flowpath being defined between the stator assembly and the rotor assembly, and an array of deflectors exposed to the flow of leakage fluid and defining a number of discrete inter-deflector passages through which the leakage fluid flows before being discharged into the working fluid flowpath, each of said deflectors having a leading end pointing into the oncoming flow of leakage fluid and a concave surface redirecting the leakage fluid from a first direction to a second direction substantially tangential to a direction of the working fluid.

In another aspect, the present invention provides a rotor blade extending into a working fluid flow path of a gas turbine engine, the rotor blade comprising an airfoil portion extending from a first side of a platform, and an array of deflectors provided on said first side of the platform at a front end portion thereof upstream of said airfoil portion, the deflectors defining a series of inter-deflector passages curving from a first direction to a second direction substantially tangential to the flow of working fluid flowing over said airfoil portion.

In another aspect, the present invention provides a turbine blade for attachment to a rotor disc of a gas turbine engine having an annular gaspath in fluid flow communication with a fluid leakage path, the turbine blade extending radially outwardly from the rotor disc into the annular gaspath; the turbine blade comprising an airfoil portion extending from a

first side of a platform and a root portion extending from an opposite second side of the platform, and an array of deflectors provided on a front end of the platform, the deflectors having a first end and a second end, the first end adjacent the leading edge of the platform and the second end extending away from the leading edge towards the airfoil portion, the deflectors having a convex side and a concave side oriented in opposite relation to a concave surface of the airfoil portion, the concave side of the deflectors scooping a fluid flow exiting the leakage path and redirecting the fluid to enter the gaspath in a direction substantially tangential to a direction of the gaspath flow.

In another aspect, the present invention provides a method for improving efficiency of a gas turbine engine, comprising the steps of: channelling a flow of leakage fluid through a leakage path into a working fluid flowpath of the gas turbine engine, and redirecting the leakage fluid to enter the working fluid flowpath in a direction substantially tangential to a direction of the working fluid flow.

Further details of these and other aspects of the present invention will be apparent from the detailed description and figures included below.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying figures depicting aspects of the present invention, in which:

FIG. **1** is a schematic cross-sectional view of a gas turbine engine;

FIG. **2** is an axial cross-sectional view of a portion of a turbine section of the gas turbine engine showing a turbine blade (mounted on a rotor disk) including a deflector arrangement in accordance with an embodiment of the present invention;

FIG. **3** is a side view of the turbine blade with the deflector arrangement;

FIG. **4** is a perspective view of an array of deflectors provided on a front end portion of a platform of the turbine blade shown in FIG. **3**;

FIG. **5** is a top plan view of the array of deflectors provided on the front end portion of the platform of the turbine blade shown in FIG. **3**;

FIG. **6** is a schematic cross-sectional view of a front end portion of a platform of the turbine blade with a deflector arrangement in accordance with another embodiment of the present invention;

FIG. **7** is a perspective view of an array of deflectors formed in the front end portion of the platform of the turbine blade shown in FIG. **6**;

FIG. **8** is a top plan view of the array of deflectors provided in the front end portion of the platform of the turbine blade shown in FIG. **6**; FIG. **9** is a velocity triangle representing the original velocity of a fluid flow exiting a leakage path before being scooped and redirected by a deflector; and FIGS. **10** and **11** are possible velocity triangles representing the resulting velocity of the fluid flow when scooped and redirected by a deflector.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a gas turbine engine **10** of a type preferably provided for use in subsonic flight, generally comprising in serial flow communication through a working flow path a fan **12** through which ambient air is propelled, a multistage compressor **14** for pressurizing the air, a combustor **16** in which the compressed air is mixed with fuel and ignited for generating an annular stream of hot combustion gases, and a turbine section **18** for extracting energy from the combustion gases.

FIG. **2** illustrates in further detail the turbine section **18** which comprises among others a forward stator assembly **20** and a rotor assembly **22**. A gaspath indicated by arrows **24** for directing the stream of hot combustion gases axially in an annular flow is generally defined by the stator and rotor assemblies **20** and **22** respectively. The stator assembly **20** directs the combustion gases towards the rotor assembly **22** by a plurality of nozzle vanes **26**, one of which is depicted in FIG. **2**. The rotor assembly **22** includes a disc **28** drivingly mounted to the engine shaft (not shown) linking the turbine section **18** to the compressor **14**. The disc **28** carries at its periphery a plurality of circumferentially distributed blades **30** that extend radially outwardly into the annular gaspath **24**, one of which is shown in FIG. **2**.

Referring concurrently to FIGS. **2** and **3**, it can be seen that each blade **30** has an airfoil portion **32** having a leading edge **34**, a trailing edge **36** and a tip **38**. The airfoil portion **32** extends from a platform **40** provided at the upper end of a root portion **42**. The root portion **42** is captively received in a complementary blade attachment slot **44** (FIG. **2**) defined in the outer periphery of the disc **28**. The root portion **42** is defined by forward and rearward surfaces **46** and **48**, two side surfaces **50** and an undersurface **52**, and is typically formed in a fir tree configuration that cooperates with mating serrations in the blade attachment slot **44** to resist centrifugal dislodgement of the blade **30**. A rearward circumferential shoulder **54** adjacent the rearward surface of the root **42** is used to secure the blades **30** to the rotor disc **28**.

Thus, the combustion gases enter the turbine section **18** in a generally axial downstream direction and are redirected at the trailing edges of the vanes **26** at an oblique angle toward the leading edges **34** of the rotating turbine blades **30**.

Referring to FIG. **2**, the turbine section **18**, and more particularly the rotor assembly **22** is cooled by air bled from the compressor **14** (or any other source of coolant). The rotor disc **28** has a forwardly mounted coverplate **56** that covers almost the entire forward surface thereof except a narrow circular band about the radially outward extremity. The coverplate **56** directs the cooling air to flow radially outwards such that it is contained between the coverplate **56** and the rotor disc **28**. The cooling air indicated by arrows **58** is directed into an axially extending (relative to the disc axis of rotation) blade cooling entry channel or cavity **60** defined by the undersurface **52** of the root portion **42** and the bottom wall **62** of the slot **44**. The channel **60** extends from an entrance opposing a downstream end closed by a rear tab **64**. The channel **60** is in fluid flow communication with a blade internal cooling flow path (not shown) including a plurality of axially spaced-apart cooling air passages **66** extending from the root **42** to the tip **38** of the blade **30**. The passages **66** lead to a series of orifices (not shown) in the trailing edge **36** of the blade **30** which reintroduce and disperse the cooling air flow into the hot combustion gas flow of the gaspath **24**.

Still referring to FIG. **2**, a controlled amount of fluid from the cooling air is permitted to re-enter the gaspath **24** via a labyrinth leakage path identified by arrows **68**. The leakage path **68** is defined between the forward stator assembly **20** and the rotor assembly **22**. More particularly, the fluid progresses through the leakage path until introduced into the gaspath **24** such that it comes into contact with parts of the stator assembly **20**, the forward surface of the coverplate **56**, the rotor disc **28**, the forward surface **46** of the root **42** and the blade platform **40**. The fluid flows through the labyrinth leakage path **68** to purge hot combustion gases that may have migrated into the area between the stator and rotor assemblies **20** and **22** which are detrimental to the cooling system. Thus, the leakage fluid creates a seal that prevents the entry of the combustion gases from the gaspath **24** into the leakage path **68**. A secondary function of the fluid flowing through the leakage path **68** is to moderate the temperature of adjacent components.

Furthermore, the fluid is introduced into the gaspath **24** by passing through a rearward open nozzle **70** defined by a back end portion of a vane platform **72** and a front end portion **74** of a blade platform **40**. A deflector arrangement **76** is included on the front end portion **74** of the blade platform **40** for directing the flow of cooling air to merge smoothly with the flow of hot gaspath air causing minimal disturbance. The deflector arrangement **76** is designed in accordance with the rotational speed of the rotor assembly **22** and the expected fluid flow velocity.

In this exemplary embodiment, the deflector arrangement **76** comprises an array of equidistantly spaced deflectors in series with respect to each other and to the front end portion **74** of the blade platform **40** as depicted in FIGS. **4**, **5**, **7**, and **8**. The array of deflectors extends transversally of the blade platform **40**. In one embodiment of the present invention, the array of deflectors **76** are provided as aerodynamically shaped winglets **78** extending from the blade platform **40** as shown in FIGS. **3** to **5**. More specifically, the winglets **78** extend radially outwards away from the blade platform **40** at a predetermined height and axially away from the front end portion **74** of the blade platform **40**. The winglets **78** are located upstream of the airfoils **32** of the blades **30**. The array of winglets **78** may be integral to the blade platform **40** or mounted thereon. Preferably, the winglets **78** are identical in shape and size, which will be discussed in detail furtheron.

In another embodiment of the present invention, the array of deflectors **76** are provided as aerodynamically shaped lands between adjacent grooves **80** defined in the blade platform **40** as shown in FIGS. **6** to **8**. Similar to the winglets **78**, the array of grooves **80** are in series along the front end portion **74** of the platform **40** and extend axially away therefrom. Preferably, the grooves **80** are integrally formed with the platform **40** such as by machining or casting. Notably, the depth and axial length of the grooves **80** as shown in FIGS. **6** and **7** may vary. Also, the grooves **80** are preferably identical in shape and size as will be discussed furtheron.

At this point it should be stated that both deflector embodiments described above provide the same functionality and therefore any description to follow applies to both embodiments as well as to any other equivalents. It is to be understood that the deflector **76** may be provided in various shapes and forms and is not limited to an array thereof.

Referring concurrently to FIGS. **5** and **8**, each deflector **76** of the array of deflectors has a concave side **82** and a convex side **84** defining a "J" shape profile. Another possible shape for the deflectors is defined by a reverse "C" shape profile. Each deflector **76** extends axially between a first end or a leading edge **86** and a second end or a trailing edge **88** thereof. The leading edges **86** of the deflectors **76** are adjacent to the front edge of the blade platform **40**. The concave sides **82** of the array of deflectors **76** are oriented to face the oncoming fluid flow exiting the leakage path **68**, the direction of which is indicated by arrows **90**. Each deflector **76** has a curved entry portion curving away from the direction of flow of the oncoming leakage air and merging with a generally straight exit portion. The deflectors **76** are thus configured to turn the oncoming leakage air from a first direction to a second direction substantially tangential to the flow of combustion gases flowing over turbine blades **30**. The curvature of the deflectors **76** is opposite to that of the airfoils **32** and so disposed to redirect the leakage air onto the airfoils **32** at substantially the same incident angle as that of the working fluid onto the airfoils **32**.

Referring now to FIGS. **9**, **10** and **11**, the arrows **90** (FIGS. **5** and **8**) represent vector V of FIG. **9** which indicates the relative velocity of the fluid flow exiting the leakage path **68**. The relative velocity vector V is defined as being relative to the rotating rotor assembly **22**, and more particularly relative to the direction and magnitude of blade rotation at the periphery of the rotor disc **28** indicated by vector U and represented by arrows **92** in FIGS. **5** and **8**. The absolute velocity of the fluid flow is indicated by vector C and is defined as being relative to a stationary observer. It can be observed from FIG. **9** that the absolute velocity C of the fluid flow exiting the leakage path **68** is less in magnitude than the magnitude of the velocity U of blade rotation. In order to have the absolute fluid flow velocity C substantially equal or greater than the blade rotation velocity U as illustrated in FIGS. **10** and **11**, the deflectors **76** are used to scoop the fluid flow and re-direct the flow in a substantially perpendicular or inclined direction to the direction of blade rotation. Thus an observer would see the leakage fluid flowing at the substantially the same or greater speed as the periphery of the rotor disc **28** rotates.

More specifically, the leading edges **86** of the deflectors **76** are pointed in a direction substantially opposite the direction of arrows **90** and in the direction of rotation of the rotor assembly **22** to produce a scooping effect thereby imparting a velocity to the cooling air leakage flow that is tangential to the gaspath flow. Test data indicates that imparting tangential velocity to the leakage air significantly reduces the impact on turbine efficiency. In fact, the scooping effect of the deflectors **76** also causes an increase in fluid momentum which gives rise to the increase in actual magnitude of the fluid flow. The fluid emerges from the deflectors **76** with an increased momentum that better matches the high momentum of the gaspath flow and with a relative direction that substantially matches that of the gaspath flow. As a result, the fluid flow merges with the hot gaspath flow in a more optimal aerodynamic manner thereby reducing inefficiencies caused by colliding air flows. Such improved fluid flow control is advantageous in improving turbine performance.

It would be apparent to a person skilled in the art that the gaspath flow travelling between the stator and rotor assemblies **20** and **22** is not axial and therefore the velocity imparted to the fluid is not completely tangential to the rotor assembly **22** axis of rotation.

The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without department from the scope of the invention disclosed. For example, the deflectors may extend up to the airfoil of the rotor blade while still imparting tangential velocity and increased momentum to the cooling air flow. The deflectors could be mounted at other locations on the rotor assembly as long as they are exposed to the leakage air in such a way as to impart added tangential velocity thereto. Also, a similar deflector arrangement could be introduced in the compressor section of a gas turbine engine for controlling the flow of air which is reintroduced back into the working flow path of the engine. Furthermore, the deflectors could be mounted on the stator assembly to impart a tangential component to the leakage air before the leakage be discharged into the working fluid flow path or main gaspath of the engine. Still other modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims.

The invention claimed is:

1. A gas turbine engine including a forward stator assembly and a rotor assembly, the rotor assembly drivingly mounted to an engine shaft having an axis, the rotor assembly having a plurality of circumferentially distributed blades that extend radially outwardly into a working fluid flowpath, a leakage path leading to the working fluid flowpath being defined between the stator assembly and the rotor assembly, and an array of deflectors exposed to the flow of leakage fluid and defining a number of discrete inter-deflector passages through which the leakage fluid flows before being discharged into the working fluid flowpath, each of said deflectors having a leading end pointing into the oncoming flow of leakage fluid and a concave surface redirecting the leakage fluid from a first direction to a second direction substantially tangential to a direction of the working fluid, wherein each of said blades has an airfoil extending from a first side of a platform, and wherein a transversal row of side-by-side grooves is defined in a front end portion of the platform, each pair of adjacent grooves being spaced by a land, the lands forming said defectors.

2. The gas turbine engine as defined in claim **1**, wherein said leading end generally points in a direction of rotation of said rotor assembly.

3. The gas turbine engine as defined in claim **1**, wherein each of said deflectors has a curved entry portion curving gradually away from a flow direction of said leakage flow, said curved entry portion merging into a substantially straight exit portion.

4. The gas turbine engine as defined in claim **1**, wherein the leading end of the deflectors is adjacent the front edge of the platform of the blades.

5. The gas turbine engine as defined in claim **4**, wherein the deflectors have a trailing end extending away from the front edge of the platform towards the airfoil and defining a "J" shape profile.

6. The gas turbine engine as defined in claim **4**, wherein the deflectors have a trailing end extending away from the front edge of the platform towards the airfoil and defining a reverse "C" shape profile.

7. A rotor blade extending into a working fluid flow path of a gas turbine engine, the rotor blade comprising an airfoil portion extending from a first side of a platform, and an array of deflectors provided on said first side of the platform at a front end portion thereof upstream of said airfoil portion, the deflectors defining a series of inter-deflector passages curving from a first direction to a second direction substantially tangential to the flow of working fluid flowing over said airfoil portion, wherein each of said deflectors has a leading end pointing in a direction of rotation of said rotor blade.

8. The rotor blade as defined in claim **7**, wherein each of said deflectors has a concave guiding surface oriented in opposite relation to a concave pressure surface of said airfoil portion.

9. The rotor blade as defined in claim **7**, wherein said defectors are arranged side-by-side in a row transversal to said platform.

10. The rotor blade as defined in claim **7**, wherein each of said deflectors has a leading end adjacent the front edge of the platform.

11. The rotor blade as defined in claim **10**, wherein each of the deflectors has a trailing end extending away from the front edge of the platform towards the airfoil and defining a "J" shape profile.

12. The rotor blade as defined in claim **10**, wherein each of the deflectors has a trailing end extending away from the front edge of the platform towards the airfoil and defining a reverse "C" shape profile.

13. The rotor blade as defined in claim **7**, wherein the array of deflectors are provided as winglets extending radially outwards from the first side of the platform.

14. The rotor blade as defined in claim **7**, wherein a transversal row of side-by-side grooves is defined in the front end portion of the platform, each pair of adjacent grooves being spaced by a land, the lands fanning said deflectors.

15. A turbine blade for attachment to a rotor disc of a gas turbine engine having an annular gaspath in fluid flow communication with a fluid leakage path, the turbine blade extending radially outwardly from the rotor disc into the annular gaspath; the turbine blade comprising an airfoil portion extending from a first side of a platform and a root portion extending from an opposite second side of the platform, and an array of deflectors provided on a front end of the platform, the deflectors having a first end and a second end, the first end adjacent the leading edge of the platform and the second end extending away from the leading edge towards the airfoil portion, the deflectors having a convex side and a concave side oriented in opposite relation to a concave surface of the airfoil portion, the concave side of the deflectors scooping a fluid flow exiting the leakage path and redirecting the fluid to enter the gaspath in a direction substantially tangential to a direction of the gaspath flow.

16. The turbine blade as defined in claim **15**, wherein said first end points in a direction of rotation of said turbine blade.

17. The rotor blade as defined claim **15**, wherein said deflectors are arranged side-by-side in a row transversal to said platform.

18. A method for improving efficiency of a gas turbine engine, comprising the steps of: a) channelling a flow of leakage fluid through a leakage path into a working fluid flowpath of the gas turbine engine, the leakage path being defined between a row of stator vane and a row of rotor blades, each of said rotor blades having a platform, and b) redirecting the leakage fluid to enter the working fluid flowpath in a direction substantially tangential to a direction of the working fluid flow, wherein step b) comprises channelling the leakage fluid through a series of grooves defined in the platforms of the rotor blades.

19. A rotor blade extending into a working fluid flow path of a gas turbine engine, the rotor blade comprising an airfoil portion extending from a first side of a platform, and an array of deflectors provided on said first side of the platform at a front end portion thereof upstream of said airfoil portion, the deflectors defining a series of inter-deflector passages curving from a first direction to a second direction substantially tangential to the flow of working fluid flowing over said airfoil portion, wherein each of said deflectors has a concave guiding surface oriented in opposite relation to a concave pressure surface of said airfoil portion.

20. A rotor blade extending into a working fluid flow path of a gas turbine engine, the rotor blade comprising an airfoil portion extending from a first side of a platform, and an array of deflectors provided on said first side of the platform at a front end portion thereof upstream of said airfoil portion, the deflectors defining a series of inter-deflector passages curving from a first direction to a second direction substantially tangential to the flow of working fluid flowing over said airfoil portion, wherein a transversal row of side-by-side grooves is defined in the front end portion of the platform, each pair of adjacent grooves being spaced by a land, the lands forming said deflectors.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,244,104 B2

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INVENTOR(S) : Sami Girgis and Remo Marini

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the claim:

Column 7, line 15, delete “fanning” insert --forming--

Signed and Sealed this

Thirtieth Day of October, 2007

JON W. DUDAS

Director of the United States Patent and Trademark Office